CHAPTER 6 Cast-In-Drilled-Hole Piles

Description

Few terms are as self-descriptive as the one given the Cast-In-Drilled-Hole (CIDH) pile. They are simply reinforced concrete piles cast in holes drilled to predetermined elevations. Much experience has been gained with this pile type because of their extensive use in the construction of bridge structures. While they probably are the most economical of all commonly used piles, their use is generally limited to certain ground conditions.

The ground formation in which the holes for CIDH piles are to be drilled must be of such a nature that the drilled holes will retain their shape and will not cave in when concrete is placed. Because of cave-in and concrete placement difficulties, these piles are not recommended for use as battered piles. Nor are they recommended where groundwater is present, unless dewatering can be done without unreasonable effort and unless concrete can be placed without a casing having to remain in place. If groundwater or caving conditions are present, the piles can be constructed by the slurry displacement method if permitted in the contract specifications. The slurry displacement method is described in detail in Chapter 9 of this manual.

Specifications

The Standard Specifications describe two different types of CIDH pile. The first type is the cast-in-drilled-hole pile. The second type is the cast-in-driven-steel-shell pile. For this type of pile, a steel shell is driven to a specified tip elevation and bearing value. The material within the steel shell is then removed and the steel shell is filled with reinforced or non-reinforced concrete.

The Standard Specifications contain much of the information necessary to administer the construction of CIDH piles. Section 49-4 contains information on the construction method and hole drilling. Section 52 contains information on pile bar reinforcement. Section 90 contains information on the concrete mix design, transportation of concrete, and curing of concrete used for CIDH piles.

The Special Provisions contain job-specific requirements and revised specifications. Because the CIDH pile specifications are continually updated, it is very important that the Structure Representative carefully review the Special Provisions and any revised specifications noted should be discussed with the Contractor.

Drilling Equipment

The drilling auger is the most commonly used piece of equipment for drilling holes for CIDH piles. Augers may be used in granular and cohesive materials.

There are two basic varieties of augers—the standard short section (Figure 6-1) and continuous flight. Both have flights of varying diameter and pitch.

Continuous flight augers have flight lengths which are longer than the hole to be drilled. They are generally lead-mounted. The power unit is located at the top of the auger and it travels down the leads with the auger as the hole is drilled. Drilling is performed in one

Figure 6-1: Auger – Short Section

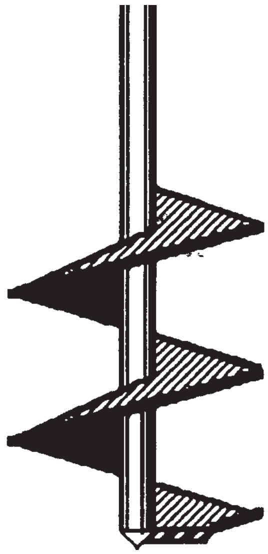


Figure 6-2: Auger – Single Flight

continuous operation. As the auger moves down the hole, the drilling action of the flights forces the drill cuttings up and out of the hole. Hence, much material has to be shoveled away from around the drilled hole. Continuous flight augers are most commonly used for short piles or for predrilling for driven piles. They may also be used where overhead clearance is not a problem.

Short flight augers are powered by ''Kelly Bar'' units fixed to the drill rig. The length of these augers generally vary between 5 and 8 feet. The auger is attached to the end of the Kelly Bar and, as drilling progresses, the auger (and material carried on the flights) must be removed frequently. After the auger is removed from the drilled hole, the material is ''spun'' off the flights onto a spoil pile and the operation is repeated.

There are also a variety of different types of augers that may be used in different situations. Augers may be single flight (Figure 6-2) or double flight (Figure 6-3). Double flight augers are better balanced than single flight augers and are more useful when alignment and location of the drilled hole are important due to clearance or right-of-way problems.

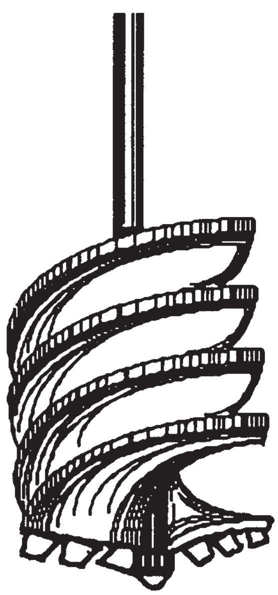


Figure 6-3: Auger – Double Flight

Soil augers are equipped with a cutting edge that cuts into the soil during rotation. The drill cuttings are carried on the flights as the auger is removed from the drilled hole and are then ''spun'' off. The pitch of the flights can vary and should be chosen for the type of material encountered. Soil augers may not work well in cohesionless materials where the soil will not stay on the flights during auger extraction. They may also not work well in highly cohesive materials where the auger may become clogged.

Rock augers are equipped with high-strength steel cutting teeth that can cut through soft rock. These augers typically have flights with a very shallow pitch so that rock pieces, cobbles and boulders can be extracted. Rock augers are generally the preferred tool for drilling in materials that have a high concentration of cobbles or boulders.

Figure 6-4: Drilling Bucket

Drilling buckets (Figure 6-4) are used when augers are not able to extract material from a drilled hole. This can happen when wet materials or cohesionless materials are encountered. Drilling buckets may also be appropriate when heavy gravel or cobbles are encountered. Drilling buckets have a cutting edge which forces material into the bucket during rotation. When the drilling bucket is full, the bucket is spun in the direction opposite of drilling to close the built-in flaps, which prevent the cuttings from falling out of the bucket. The bucket is then extracted from the drilled hole and emptied.

Cleanout buckets are specialized drilling buckets that are used to clean loose materials from the bottom of a drilled hole and to flatten the bottom of the drilled hole. This allows the tip of the pile to be founded on a firm flat surface. These buckets have no cutting teeth but are similar to drilling buckets in other aspects. Specialized cleanout buckets can be used to extract loose materials when groundwater or drilling slurry is present. These buckets, referred to as "muckout" buckets, allow fluid to pass through them while retaining the loose materials from the bottom of the drilled hole. Figure 6-5 shows the difference between the cleanout bucket and the drilling bucket.

Figure 6-5: Drilling Bucket/Cleanout Bucket Comparison

Figure 6-6: Core Barrel

Core barrels (Figure 6-6) are used to drill through hard rock formations, very large boulders or concrete. This type of drilling tool consists of a steel cylinder with hard metal cutting teeth on the bottom. Rock cores are broken off and extracted from the drilled hole as a single unit, or may be broken up with a rock breaker and then extracted with a drilling bucket or clamshell.

Drilling is performed almost exclusively with portable drilling rigs. These units can be self-propelled (Figure 6-7), truck-mounted (Figure 6-8), or crane-mounted (Figure 6-9).

Figure 6-7: Drill Rig – Crawler Mounted

Figure 6-8: Drill Rig – Truck Mounted

Figure 6-9: Drill Rig – Crane Mounted

Figure 6-10: Steel Casing

Steel casings (Figure 6-10) are used to support drilled holes when unstable conditions are encountered. Various methods have been used to advance steel casings, among them, spinning the casing with the Kelly Bar while applying some vertical force, driving the casing with whatever means are available as the hole is drilled, or using a vibratory hammer. Steel casings are generally extracted from the hole in the manner specified in the contract specifications as concrete is placed.

Drilling Methods

Various other materials are used to supplement the drilling work. Water is sometimes added to certain ground formations to assist drilling and lifting materials from the hole. Soil may be placed back into the hole to dry out supersaturated materials. The drilling tool is used to agitate the materials so they can be extracted from the hole. This is known as "processing" the hole.

Drilling Problems

The difficulties encountered in drilling can include cave-ins, groundwater, and utilities. The following briefly describes some actions which can be taken in these situations.

In the case of cave-ins, the following action or combination thereof may be required:

ITEM	ACTION
1	Placement of a low cement/sand mix and redrilling the area of the cave-in.
2	If permitted by the contract Special Provisions, use of a drilling slurry (refer to Chapter 9 of this manual).
3	Use of a casing which is pulled when placing concrete.

In the case of groundwater, the following action or combination thereof may be required:

ITEM	ACTION
1	Placement of a low cement/sand mix and redrilling the hole.
2	Drilling to tip elevation, using a pump to remove the water and cleaning out the bottom of the pile.
3	If permitted by the contract Special Provisions, use of a drilling slurry (refer to Chapter 9 of this manual).
4	Placement of a casing, again using a pump to remove the water, and pulling casing during concrete placing (keeping bottom of casing below the concrete surface).
5	Dewatering the entire area using well points, deep wells, etc. This should be thoroughly discussed with the Bridge Construction Engineer and the Engineering Geologist.
6	By contract change order, substitute an alternative type of piling. Again, this should be discussed with the Project Designer, the Engineering Geologist, and the Bridge Construction Engineer.

Operations should proceed with caution when drilling near utilities known or thought to be in close proximity. The Contractor should contact the utility company and have the utility located. It is also advised that the Contractor pothole and physically locate the utility prior to drilling. Relocation of the utility may be required. Minor adjustments in pile location might be feasible in order to avoid conflict. Any proposed revisions to the pile layout should be discussed with the Project Designer, the Engineering Geologist, and the Bridge Construction Engineer.

In the case of problems with groundwater, cave-ins or obstructions at the lower portion of the hole and under certain conditions, the Standard Specifications allow the Contractor to propose increasing the pile diameter in order to raise the pile tip. Before allowing this, the Structure Representative should consult with the Project Designer and Engineering Geologist to see if this is feasible, and if so, to obtain the revised tip elevation. Appropriate pay provisions are also included in the contract specifications and a change order is not required.

Ordinarily, the above problems would stimulate the Contractor's action and a change would be proposed to the Structure Representative.

Inspection

Before drilling begins, it is advisable to have a pre-construction meeting with the Contractor and any subcontractors that will be involved in the work. Items to be discussed should include any recently revised contract specifications, the contract pay limits, the Contractor's planned method of operation, the equipment to be used, the plan for avoiding existing utilities (if any), and safety precautions to be taken during the work.

The Structure Representative should review the contract plans, the Foundation Report and the Log of Test Borings thoroughly. If there are any discrepancies noted between the pile type shown on the plans, the pile type called for in the Foundation Report, and the soil materials and groundwater level shown on the Log of Test Borings, the Project Designer should be contacted for clarification.

Due to recent changes in design practice, it is possible that the pile may not be designed for end bearing alone. The Project Designer should be contacted to determine whether skin friction has a role in the capacity of the pile. This is especially true of seismic retrofit projects, where pile tensile capacity may be a requirement.

The Contractor is required to lay out the pile locations at the site prior to drilling. This layout should be checked by the Structure Representative prior to drilling. The Structure Representative should also set reference elevations in the area so pile lengths and pile cutoff can be ascertained.

During the drilling operation, the Structure Representative should verify that the piles are being drilled in the correct location and are plumb. Usually, the Contractor will check the Kelly bar with a carpenter's level during the drilling operation. The Structure Representative should also evaluate the material encountered and compare it to that shown on the Log of Test Borings. If the material at specified tip differs from that anticipated, a change may be needed. It may be advisable to keep a written record of the drilling progress and the record utilized to investigate any differing site conditions claims submitted by the Contractor.

When the hole has been drilled down to the specified tip elevation, the Contractor should always use a cleanout bucket to remove any loose materials and to produce a firm flat surface at the bottom of the drilled hole.

After drilling, the depth, diameter and straightness of the drilled hole must be checked. The drilled hole should be checked using a suitable light, furnished by the Contractor, or a mirror. At this time, the Structure Representative should measure and record the length of each pile. Unless the Structure Representative orders the Contractor, in writing, to change the specified tip elevation, no payment will be made for any additional depth of pile below the specified tip elevation.

For large diameter piles, it may be necessary for the Structure Representative or the Engineering Geologist to inspect the bearing surface at the bottom of the drilled hole. All pertinent requirements of the Construction Safety Orders shall be met before anyone enters the drilled hole.

Immediately before placing concrete, the bottom of the drilled hole should be checked for loose materials or water. Loose materials and small amounts of water can be removed with a cleanout bucket. Large amounts of water may need to be pumped out. It may be necessary to remove the rebar cage to accomplish this. Steel reinforcement cage clearances and blocking should also be checked at this time. In addition, the reinforcing cage must be adequately supported and some means must be devised to ensure concrete placement to the proper pile cutoff elevation.

Concrete placement warrants continuous inspection. This subject is covered comprehensively in the contract specifications. Those involved in the work should thoroughly review Standard Specifications Sections 49-4 and the contract Special Provisions. Applicable portions of Section 90 should also be reviewed with respect to concrete mix design, consistency of the concrete mix, and concrete curing requirements.

Pile Defects

The drilling problems mentioned previously, if not corrected, can cause CIDH piles to be defective. There are also problems that can occur during concrete placement or casing removal that can cause defective CIDH piles.

The following drilling problems can cause pile defects:

ITEM	DRILLING PROBLEM/PILE DEFECT
1	The Contractor does not clean off the bottom of the drilled hole with a cleanout bucket. This can result in the pile bearing on soft material. For CIDH piles designed for end bearing, this flaw can seriously compromise the value of the pile. This defect is shown in Figure 6-11.
2	The Contractor uses a tapered auger to advance the drilled hole to the specified tip elevation and does not flatten the bottom of the hole with a cleanout bucket. This can result in concrete crushing at the tip of the pile, which would reduce its capacity and possibly cause differential settlement. There may also be soft material at the tip of the drilled hole, which would cause the problems mentioned previously. This defect is also shown in Figure 6-11.
3	The drilling operation smears drill cuttings on the sides of the drilled hole. This can result in the degradation of the pile's capacity to transfer loads through skin friction. This may be critical if the pile is designed as a tension pile. This condition is most likely to occur in ground formations containing cohesive materials. This defect is shown in Figure 6-12.

These problems are preventable. Adherence to the contract specifications and timely inspection will eliminate most of these problems.

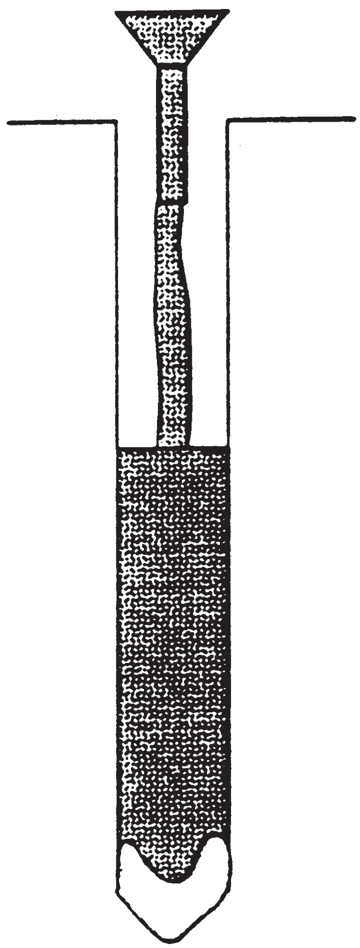


Figure 6-11: Pile Defects
No Cleanout, Tapered Bottom of Hole

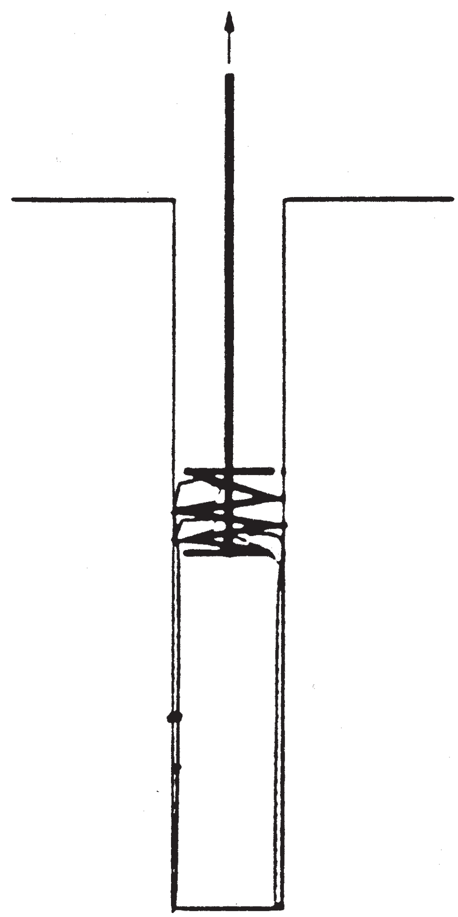


Figure 6-12: Pile Defects
Smeared Drill Cuttings

The following concrete placement problems can cause pile defects:

ITEM	CONCRETE PLACEMENT PROBLEM/PILE DEFECT
1	A cave-in at a location above the top of concrete or sloughing material from the top of the drilled hole occurs during concrete placement. This can result in degraded concrete at the location, thus reducing the capacity of the pile. This defect is shown in Figure 6-13.
2	The Contractor tailgates concrete into the drilled hole without the use of a hopper or elephant trunk to guide it. The concrete falls on the rebar cage or supporting bracing and segregates. This can result in defective concrete, thus reducing the capacity of the pile. This defect is shown in Figure 6-14.
3	A new hole is drilled adjacent to a freshly poured pile or concrete is placed in a drilled hole that is too close to an adjacent open drilled hole. This can result in the sidewall blowout of freshly poured piled into the adjacent drilled hole. This would probably cause the rebar cage to buckle. This defect is shown in Figure 6-15.
4	The Contractor does not remove groundwater from the drilled hole. This groundwater mingles with the concrete placed and may result in defective concrete at the bottom of the pile. If the pile is designed for end bearing, the capacity would be reduced. This defect is shown in Figure 6-16.

Most of these problems are preventable. Adherence to the contract specifications and timely inspection will prevent most of these problems. However, if a cave-in occurs during concrete placement, the Contractor may need to remove the rebar cage and concrete, and then start over.

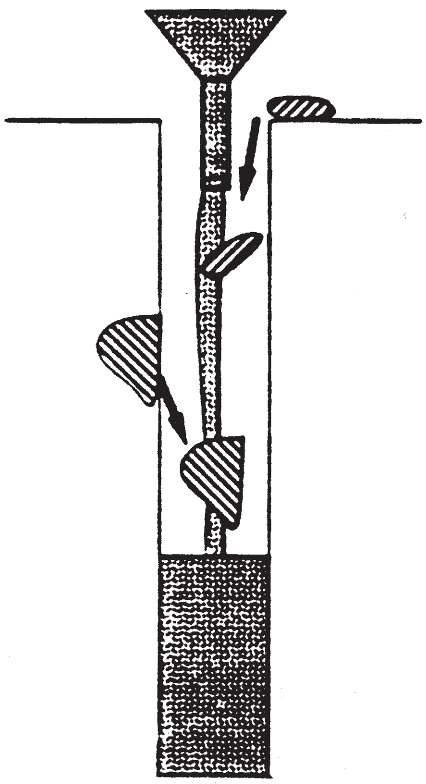


Figure 6-13: Pile Defects
Cave In

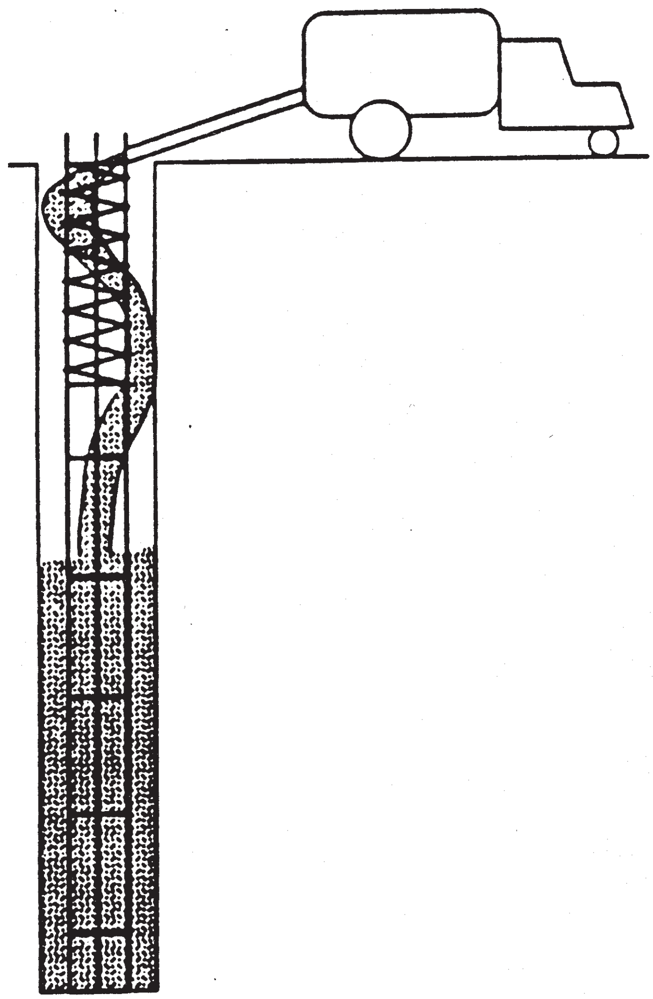


Figure 6-14: Pile Defects
Concrete Segregation

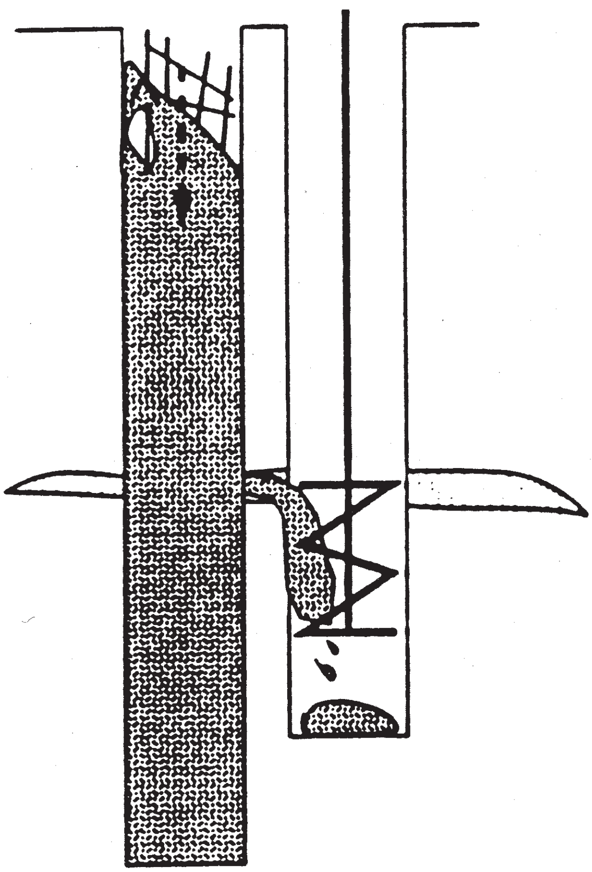


Figure 6-15: Pile Defects
Adjacent Hole Blowout

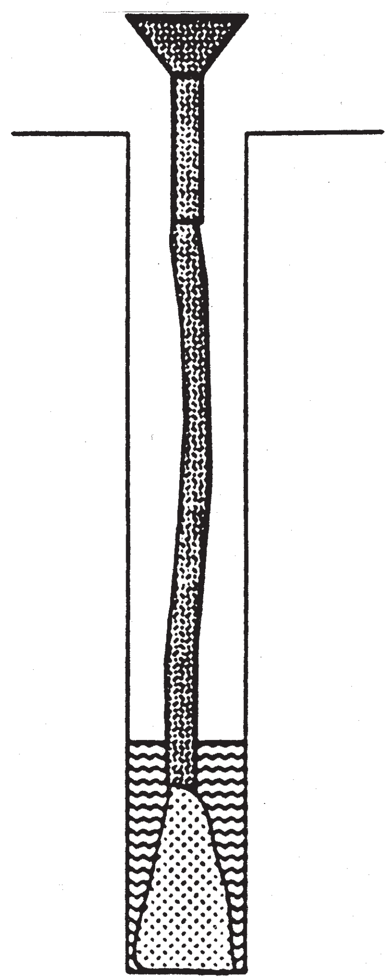
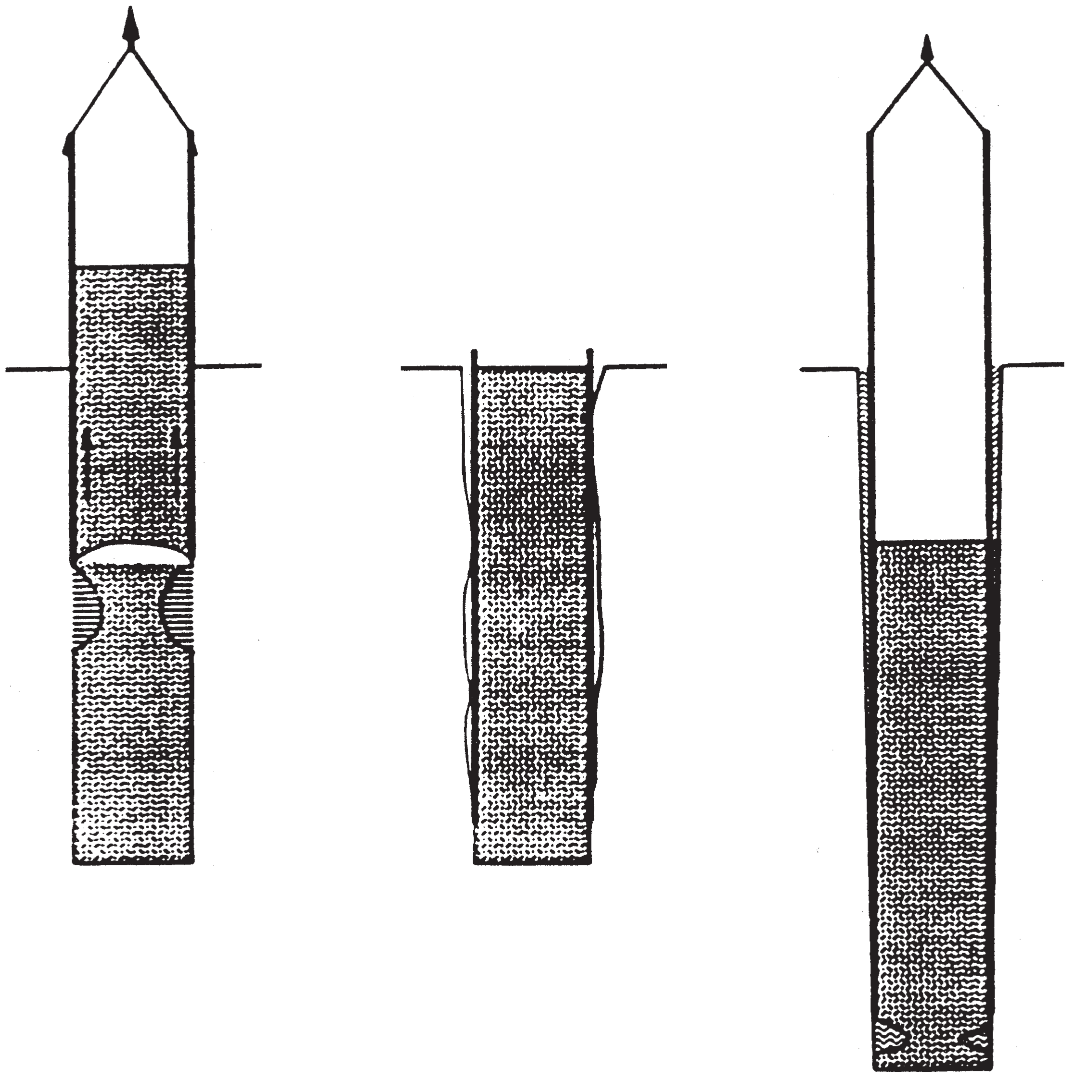


Figure 6-16: Pile Defects
Water in the Hole

The following casing removal problems can cause pile defects:

ITEM	CASING REMOVAL PROBLEM/PILE DEFECT
1	The Contractor waits too long to pull the casing during concrete placement. This may result in three problems: (1) the concrete sets up and comes up with the casing as shown in Figure 6-17(a), (2) the concrete sets casing cannot be removed as shown in Figure 6-17(b), and (3) the concrete sets up enough so that it cannot fill the voids left by the casing as it is removed, as shown in Figure 6-17(c). The first problem may result in a void being formed in the pile at the bottom of the casing. It is possible that the suction created may cause a cave-in at this location. The second and third problems result in the loss of the pile's capacity to transfer skin friction to the ground.

Historically, problems with casings have produced the largest number and the worst type of CIDH pile defects. However, these problems are preventable. Adherence to the contract specifications and timely inspection will prevent most of these problems. It is recommended to allow the penetration value of the concrete placed in the pile to be at the high end of the allowable range. Research has shown that concrete with higher fluidity will consolidate and fill in the voids better than concrete with lower fluidity. To further prevent CIDH pile defect problems when casings are used in construction the CIDH pile contract specifications have been revised so that all CIDH piles constructed with the use of temporary casings will be tested for structural adequacy prior to acceptance. The pile testing methods used to test piles constructed by the slurry displacement method (as described in Chapter 9 of this manual) would be used in this circumstance.



(a) (b) (c)

Figure 6-17: Pile Defects
Casing Problems

Safety

As with all construction activities, the Structure Representative should be aware of safety considerations associated with the operation. As a minimum, the Structure Representative shall review the Construction Safety Orders that pertain to this work. A tailgate safety meeting should be held to discuss the inherent dangers of performing this work before the work begins.

The primary and obvious hazard encountered with CIDH pile construction is the open drilled hole. Common practice is to keep the drilled hole covered with plywood, especially if the drilled hole is left open overnight. This provides protection not only for the construction crew working in the area, but also the public. In urban areas, more stringent measures may be required to secure the site.

As with any other type of operation, common sense safety practices should be used when working around this equipment. If you do not need to be there, stay away from the equipment. If a crane-mounted drilling rig is used, the crane certificate should be checked.

In addition, footing excavations should be properly sloped or shored. Imposed loads, such as those from cranes and transit mix concrete trucks, must be kept a sufficient distance from the edge of the excavation. If the Contractor intends to place equipment of this type adjacent to the excavation, the load must be considered in the shoring design and/or in determining the safe slope for unshored excavations.